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Aircraft Emissions Reductions Through Improved Operations En-Route and Around Terminal Areas

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April 6th, 2001

Outline

- **Introduction**

- **Objective of the study**

- **Technical approach**

- **Main results**

- **Conclusions**

Aircraft Emissions Reductions

- **Aviation is a significant source of greenhouse gases (GHGs)**

- **Aircraft global CO_2 anthropogenic emissions:**
  - 1992: 0.14 GtC/year   (2% of world total)
  - 2050: 0.28 - 1.5 GtC/year (4% - 21% of world total)

- **Kyoto Protocol urges developed countries to reduce total national emissions by 5% from 1990 levels for 2008-2012**

- **Two fundamental policy alternatives:**

  1. Increased stringency
     - ❏ Addresses technology
       e.g.: engines, airframes

  2. Improve operational performance
     - ❏ Addresses use of the technology
       e.g.: satellite-based navigation, Free Flight

Modeling Tools

- **Policymaking requires accurate modeling tools**

- **Current models use many simplifying assumptions**
  - ❏ Great circle routes
  - ❏ Traffic inferred from Official Airline Guide (OAG)
  - ❏ Aircraft performance determined from fleet averages

- **More detail necessary to pinpoint inefficiencies in the system**

Objective

- **Evaluate potential for emissions reductions through operational measures**

- **Introduce new methodology based on *Airline Service Quality Performance (ASQP) data:***

  - ❏ Reported information to US DoT from 10 major US carriers
  - ❏ Covers US domestic market
  - ❏ Includes: actual mission time, tailnumber for *all* flights
  - ❏ Time data separated in ground and airborne portions

  ➡ No need to use great circle routes, OAG schedule data or fleet averages

Objective (cont'd)

- **Primary goals:**

  1. Identify distribution and growth rate of ground and airborne emissions

  2. Illustrate potential for emissions reductions by comparing actual emissions to an improved scenario

- **Scope:**

  - All flights of top 10 domestic US carriers
  - Month of July of every year from 1995 to 2000

Technical approach

- **Since emissions are proportional to fuel burn, base comparisons on fuel consumption**

- **Fuel consumption calculation:**
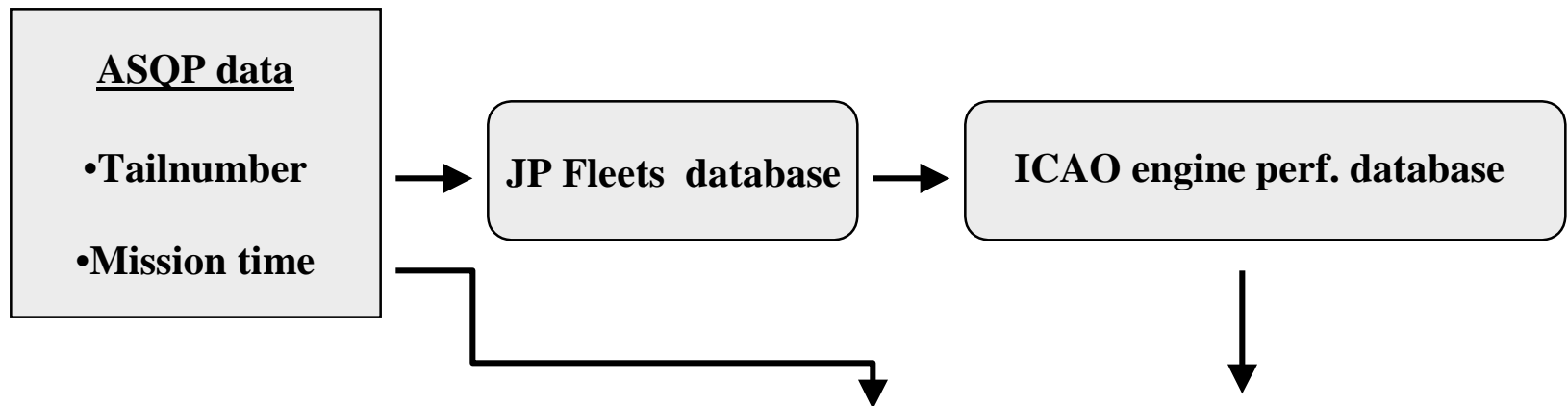
$$(\textbf{Eq. 1}) \quad \text{Fuel Flow}_i = (\text{Time} - \text{in} - \text{mode}) \cdot (\text{FF}_{\text{coefficient}})$$

$$(\textbf{Eq. 2}) \quad \text{Fuel Flow}_{\text{total}} = \sum \text{Fuel Flow}_i$$

Ground fuel consumption

- **Baseline ground fuel consumption:**
  - Approximate uninterrupted travel times between gate and runway
  - Obtain distribution of taxi-out and taxi-in times during night operations (11pm-5am)
  - Assume 15th percentile value is ground Time-in-mode (TIM)

- **Actual ground fuel consumption:**
  - ASQP ground time data corresponds to actual ground TIM

Baseline airborne fuel consumption

Altitude

10.5 km —

3 km —

Cruise

Climb-out

Descent & approach

Take-off

Taxi out

Taxi-in

Time-in-mode

TIM:
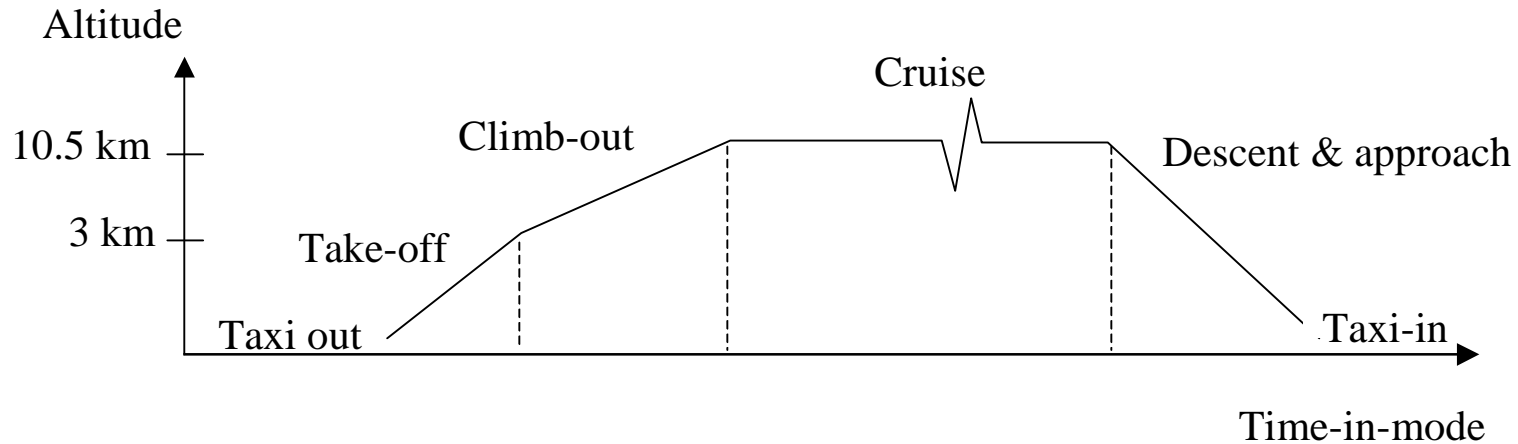
$$\left.\begin{array}{l} \mathbf{T_{take\text{-}off(base)}} \\ \mathbf{T_{climb(base)}} \\ \mathbf{T_{descent(base)}} \end{array}\right\}$$ **BADA database**

$$\mathbf{T_{cruise(base)} = 15^{th} T_{airborne(actual)} - T_{take-off(base)} - T_{climb(base)} - T_{descent(base)}}$$

Actual airborne fuel consumption

- **Must make approximations to separate ASQP airborne time data into missions segments:**

$$T_{air(actual)} = T_{take-off(actual)} + T_{cruise(actual)} + T_{Terminal\,Area\,Operations\,(TAO)}$$

- Assume:

$$T_{take-off(base)} \sim T_{take-off(actual)} \quad \rightarrow \text{ take-off inefficiencies small}$$

$$T_{cruise(base)} \sim T_{cruise(actual)} \quad \rightarrow \text{ cruise inefficiencies part of TAO}$$

$$\rightarrow \quad T_{TAO} = T_{air(actual)} - T_{take-off(actual)} - T_{cruise(actual)}$$

- **TAO captures time spent in climb, approach, descent plus all airborne delays and other inefficiencies**

- **For fuel flow calculations, assume the following:**

    ❏ Take-off → use take-off fuel flow indices

    ❏ Cruise → use cruise fuel flow indices

    ❏ TAO → Two cases:
        1. Use climb fuel flow indices: upper bound in fuel burn
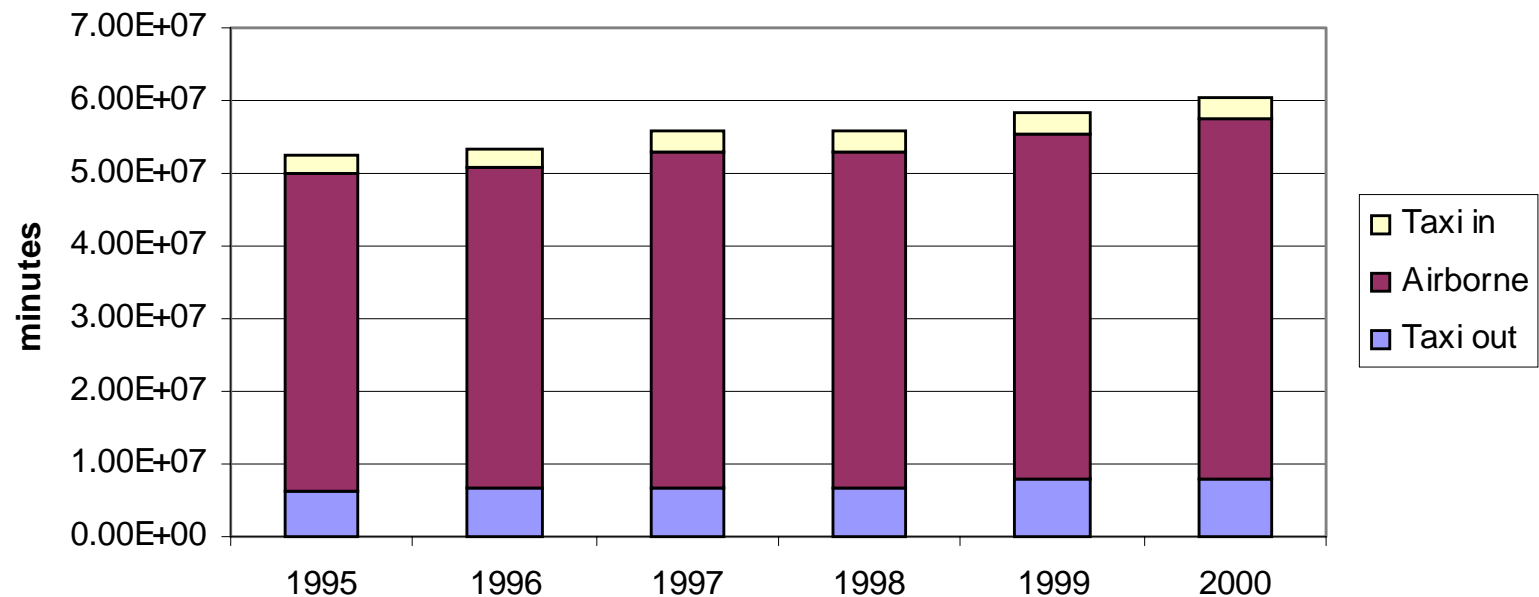   2. Use cruise fuel flow indices: lower bound in fuel burn
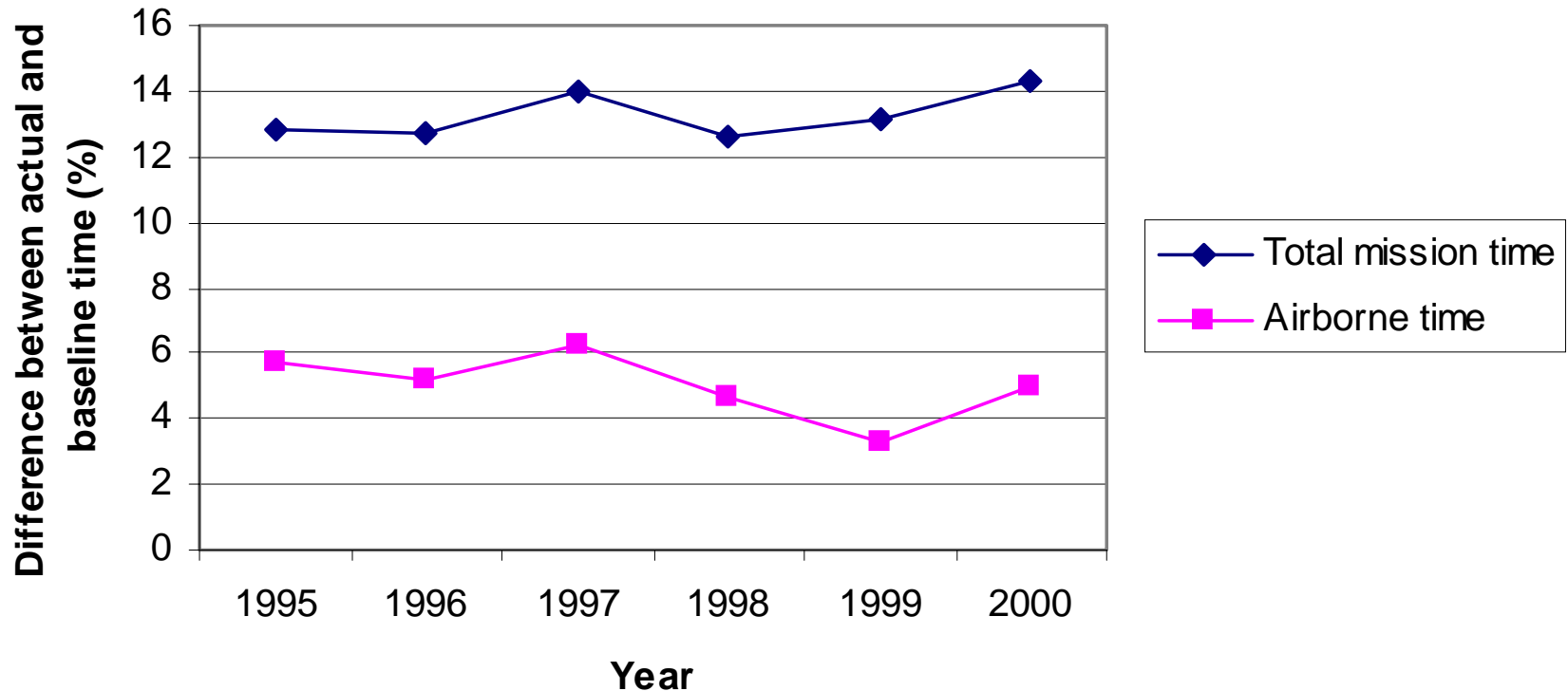
Results – Growth rates
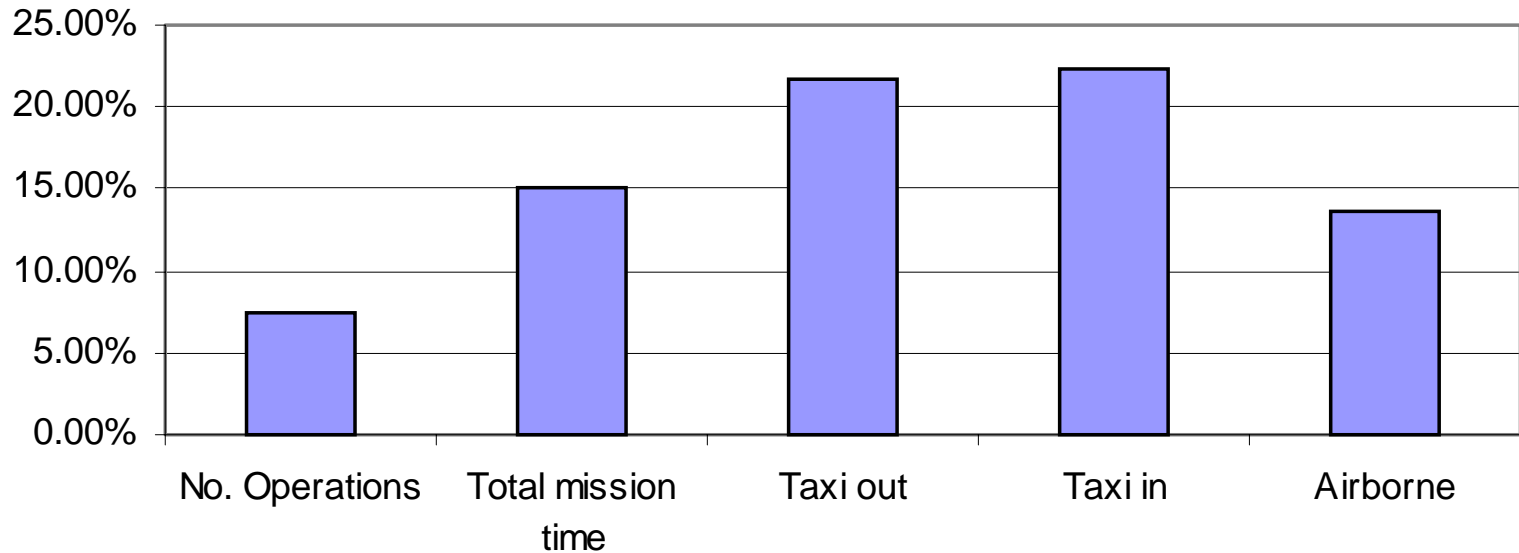
Total growth rates in US domestic aviation from July of 1995 to July of 2000.
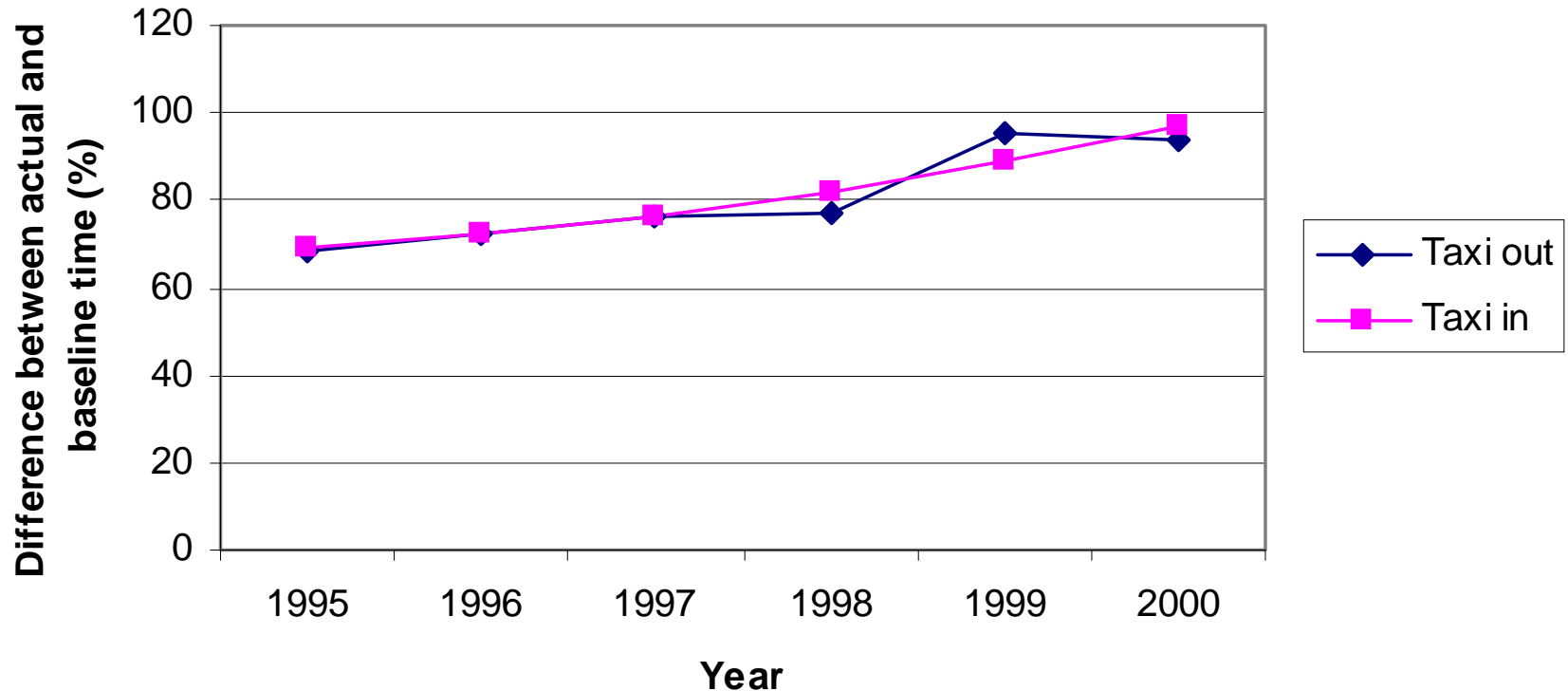
Results – T-I-M

Distribution of total mission time between ground and airborne segments for US domestic aviation in July of the indicated year (1995-2000).
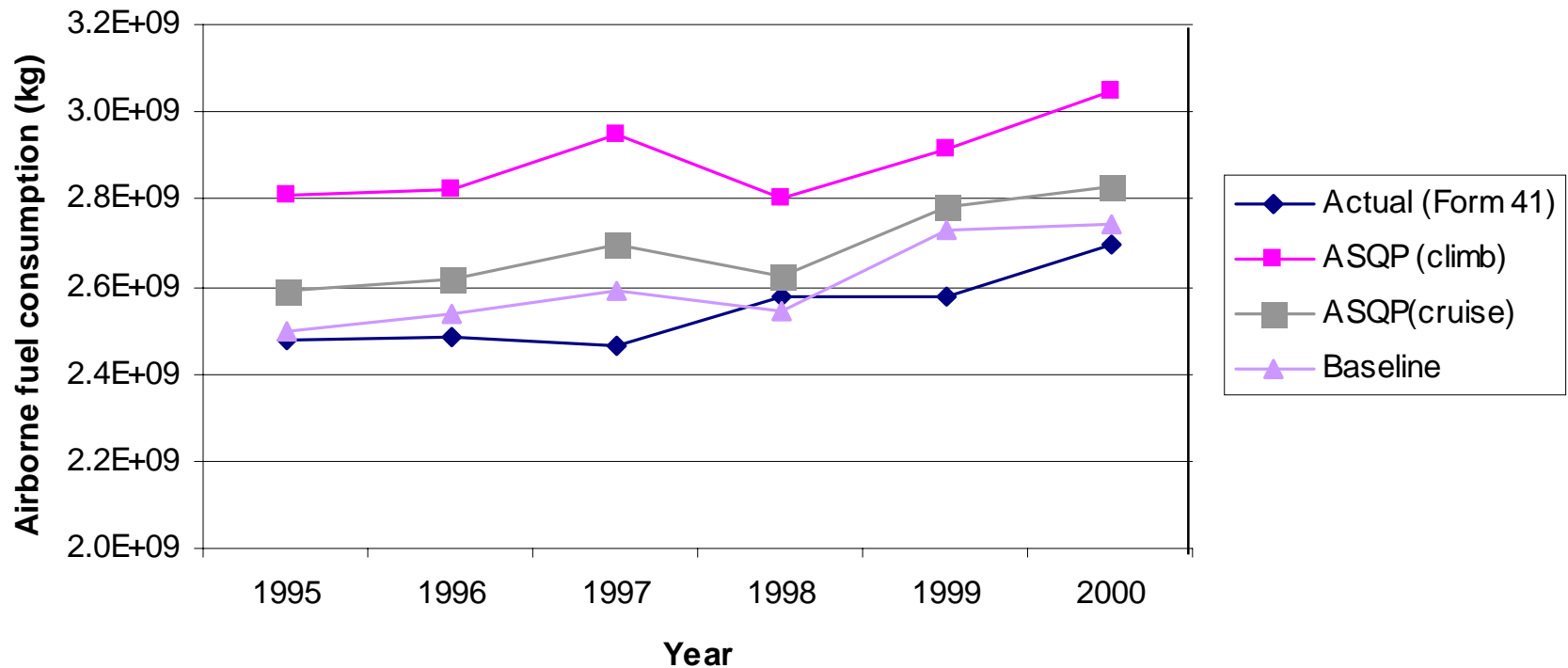
Results – Time comparison

Percentage difference between actual and baseline times for July of the indicated year (1995-2000).

Results – Ground time comparison

Percentage difference between actual and baseline times for July of the indicated year (1995-2000).

Results – Airborne fuel comparison

Airborne fuel consumption in US domestic aviation for July of the indicated year (1995-2000).

Conclusions

- **Abnormal high increase in ground times compared to overall growth in aviation**

  - ❑ Significant because ground emissions affect local air quality
  - ❑ People more sensitive to local air pollution
  - ❑ Increased ground emissions may become limiting factor for airport growth

- **Significant potential for ground emissions reductions through improved operations**

  - • In general, large reductions in taxi time possible
  - • Reductions at specific airports may vary depending on local conditions
  - • Overall emissions reductions limited because taxiing is only a fraction of total mission time

- **Significant potential for airborne emissions reductions through improved operations**

  □ Approximately between 6 -13%
    Better data on altitude profiles needed for better accuracy

- **ASQP methodology useful to refine fuel burn model but more data on flight profiles needed to take full advantage of this database**